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DATE:	March 26, 2002	**Action Item #: 1471**
RE:	Robotic Operations Inside the AMS Magnetic Field	
CC:	Crystal Haddock/ER, Bob Miley/OZ, Gene Cook/OZ, Ross Harold/Lockheed, Trent Martin/LM, Ken Bollweg/LM, Stephen Voels/OZ, Shakeel Razvi/OM, RS Library	
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The MAGIK Robotic Analysis Team has assessed the Special Purpose Dexterous Manipulator (SPDM) and Space Station Remote Manipulator System (SSRMS) robotic operations near the Alpha Magnetic Spectrometer (AMS). This action is a result of a December 13, 2001 Systems Engineering Working Group (SEWG) meeting which addressed the AMS magnetic field exposure to the Space Station robots, and is a follow-on to MAGIK Action Item 1451. Five specific questions were addressed in this action:

1. Since Action Item 1451 defined a worst case scenario for the SPDM grasping the Express Pallet (EXP) inboard-middle payload (closest to AMS), find the best case scenario for this operation with respect to least exposure to the AMS magnetic field.
2. Find the best and worst cases for the SPDM removing the outboard-middle EXP payload.
3. Find the best and worst cases for the SPDM removing the inboard-aft EXP payload.
4. Find the best and worst cases for the SPDM removing the inboard-forward EXP payload.
5. Determine the magnetic field exposure to the robots during extraction of the 22 On-orbit Replacement Units (ORUs) on S1 and S3, as defined in MAGIK Action Items 1321 and 1339.

Assumptions:

- This analysis addresses kinematic feasibility by analyzing manipulator configurations during robotic tasks. These manipulator configurations are driven by numerous constraints such as clearance with Orbiter or ISS structure, and manipulator joint limits and singularities. Areas not addressed in this document - lighting, viewing, thermal and/or pressure effects on elements, and dynamics - could have a significant influence on manipulator configurations and overall feasibility.
- 3D graphical models used in this analysis are a result of the MAGIK Team's "best efforts" to obtain/create accurate models reflecting actual volumetric dimensions of the various ISS elements. "Best efforts" include obtaining models directly from the Boeing CAD Modeling Team, the hardware designers, or a 3rd party (a source other than the hardware designers), or creating models from hardware designer or customer provided drawings/information.
- Pedigree information for pertinent models used in this analysis may be obtained from the MAGIK Team upon request.

- The trajectories and specific robot joint angles used in this analysis are not necessarily the final angles that will be used on-orbit.
- The center of the magnetic field is the origin of the AMS defined in Figure 1.
- The magnetic field x-axis is parallel to the orbiter x-axis when the AMS is manifested.
- The magnetic field y-axis is parallel to the orbiter y-axis when the AMS is manifested.
- The Gauss values given in this memo are approximated based on a mathematical interpolation of a 12,000 point magnetic field database supplied by the AMS designers.
- The Gauss values given in this memo are representative of specific SSRMS and SPDM joint configurations for the given operations. Alternative joint configurations will yield different, but similar, results.

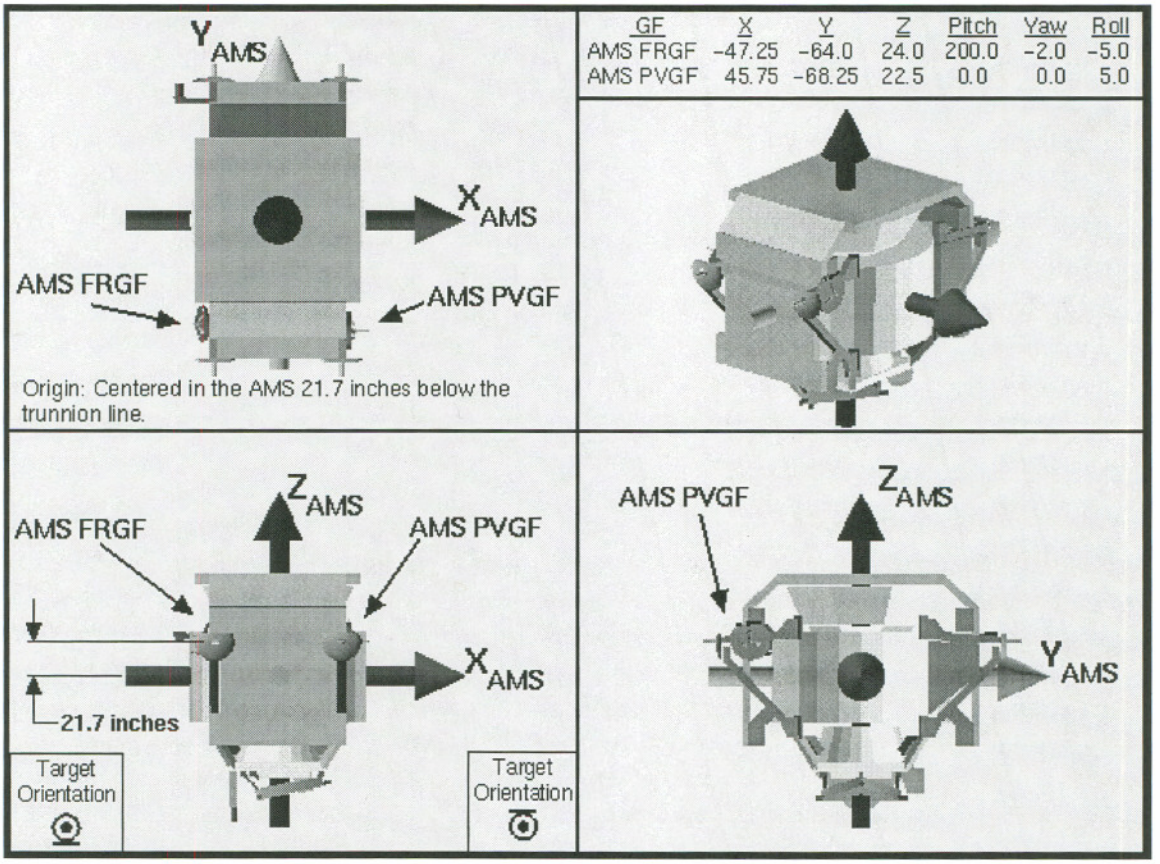

Figure 1: AMS Origin and Center of Magnetic Field

Executive Summary

The table below summarizes the magnetic field exposure to the robots for specific operations. The figures to follow are representative of these operations.

** Due to the extensive amount of work necessary to interpolate these results for each operation, and the variability of magnetic readings possible for alternative joint configurations, the MAGIK Team recommends that a "Maximum Gauss Limit" be established for each robot, with which a "keep-out" envelope could be developed. This envelope would be used in robotics analysis to determine if operations are feasible while maintaining limited magnetic exposure.

Robotic Operation	SSRMS Exposure (Gauss)	SPDM Exposure (Gauss)	SPDM Left Arm Exposure (Gauss)	SPDM Right Arm Exposure (Gauss)
1. Best – Inboard-Middle EXP Pyld Figure 2	1-5	10-17	150-750	4-16
2a. Best – Outboard-Middle EXP Pyld Figure 3	0-1	2-7	4-16	6-12
2b. Worst – Outboard-Middle EXP Pyld Figure 4	4-44	3	5-16	4-12
3a. Best – Inboard-Aft EXP Pyld Figure 5	1-4	6-11	100-370	6-16
3b. Worst – Inboard-Aft EXP Pyld Figure 6	6-27	5-23	80-200	5-16
4a. Best – Inboard-Forward EXP Pyld Figure 7	1-3	4-8	6-16	100-200
4b. Worst – Inboard-Forward EXP Pyld Figure 8	8-14	4-15	6-18	100-370
5a. S1 ORU Access Figure 9	0-1	1-5	1-4	0-2
5b. S3 ORU Access Figure 10 and Figure 11	0-2	2-9	0-3	4-22

Part 1. – Find the best case (least magnetic exposure) for the SPDM removal of the EXP Inboard-Middle Payload

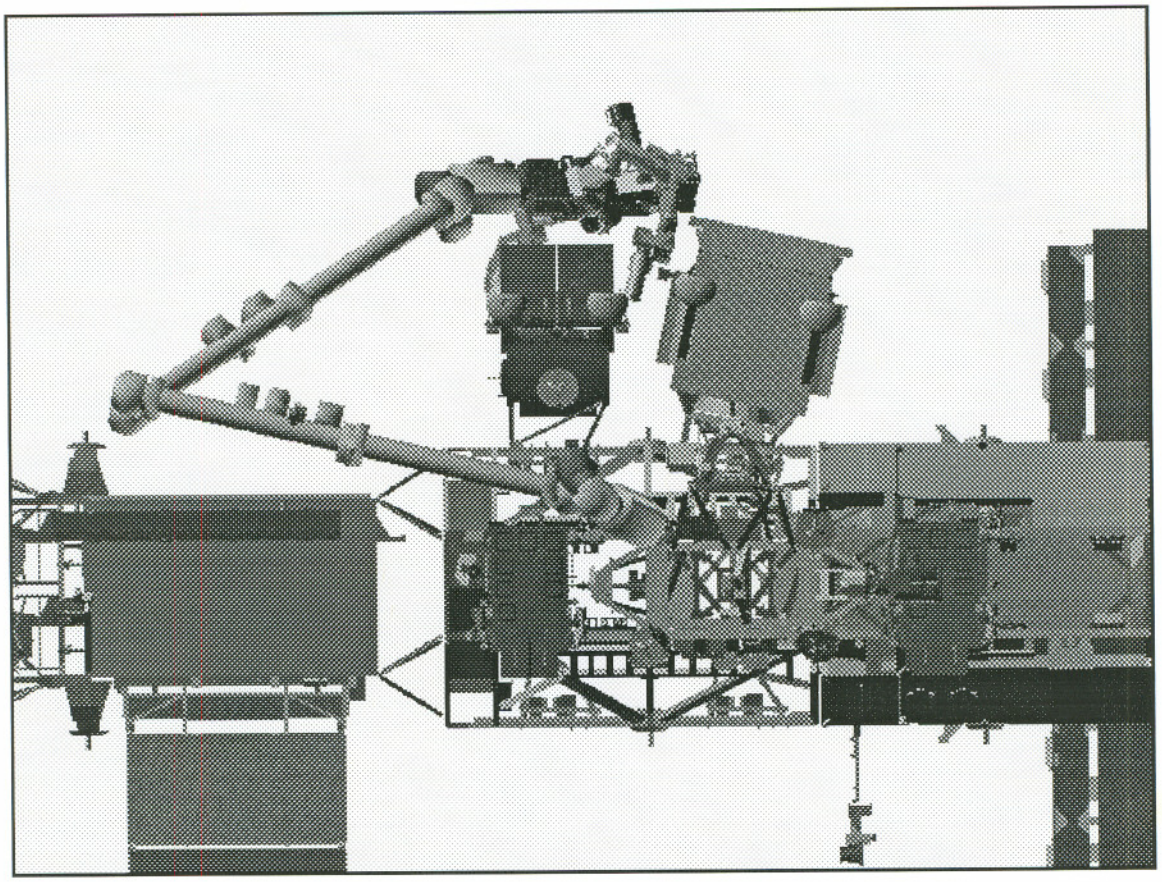

Figure 2: SPDM Grapples Inboard Middle EXP Payload
ISS Front View

Using the AMS magnetic field database from the designers, the following Gauss levels on the robots during this operation were approximated:

Affected Area	Gauss Level
SSRMS	1-5
SPDM Body and LEE	10-17
SPDM Right Arm (stabilize)	4-16
SPDM Left Arm (approach to grapple)	150-750
SPDM Left Arm (at grapple)	300-750

Part 2. – Find the best and worst cases for the SPDM removal of the EXP Outboard-Middle Payload

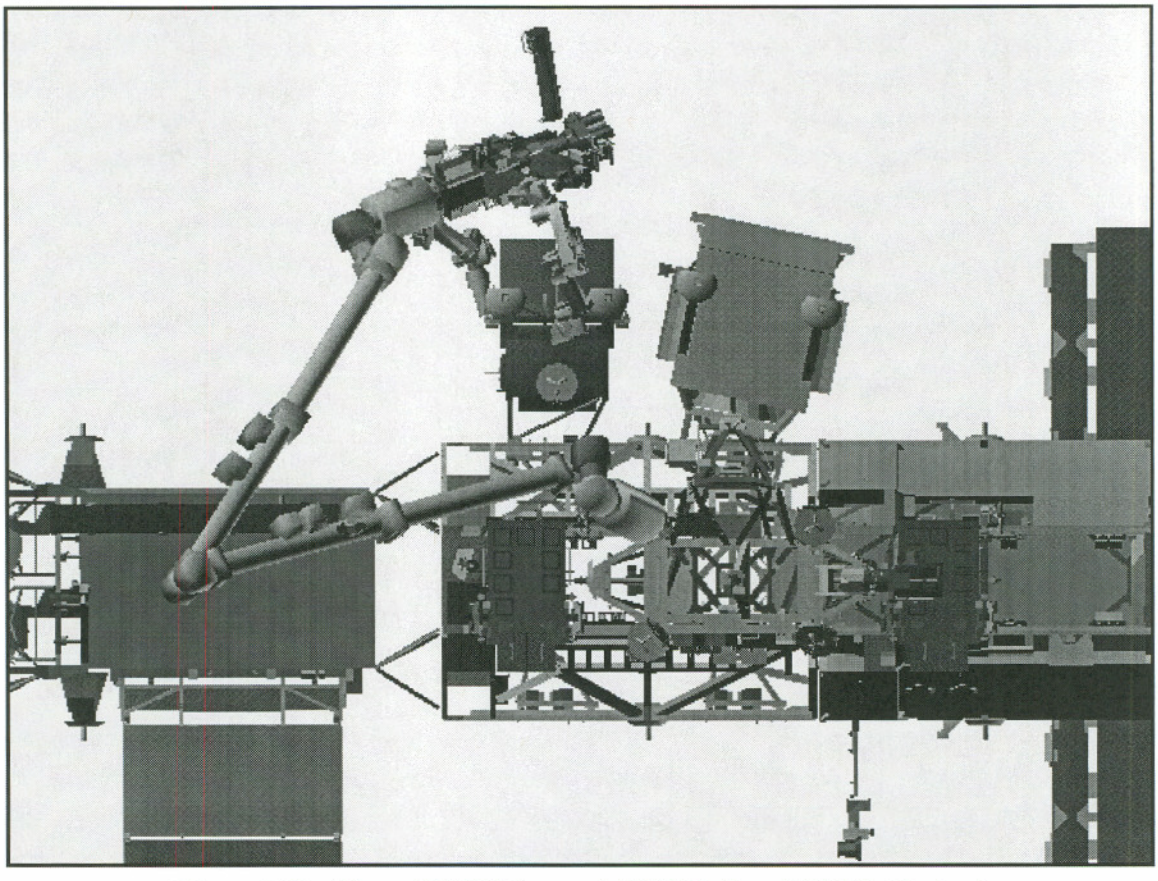

Figure 3: Best Case of SPDM Access to EXP Outboard-Middle Payload
ISS Front View

Affected Area	Gauss Level
SSRMS	0-1
SPDM Body and LEE	2-7
SPDM Rt. Arm (grasping ORU)	6-12
SPDM Lft. Arm (stabilizing)	4-16

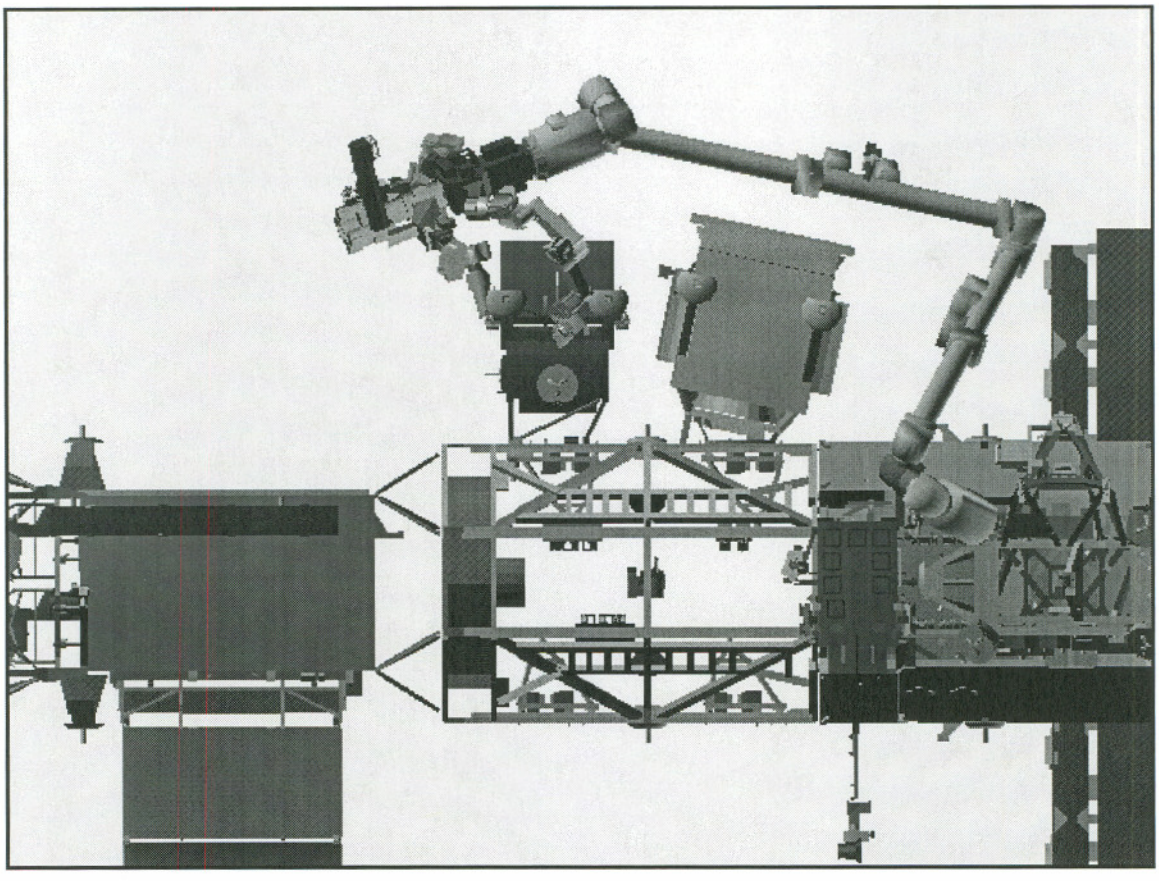

Figure 4: Worst Case of SPDM Access to EXP Outboard-Middle Payload
ISS Front View

Affected Area	Gauss Level
SSRMS	4-44
SPDM Body	3
SPDM Rt. Arm (grasping ORU)	4-12
SPDM Lft. Arm (stabilizing)	5-16

Part 3. – Find the best and worst cases for the SPDM removal of the EXP Inboard-Aft Payload

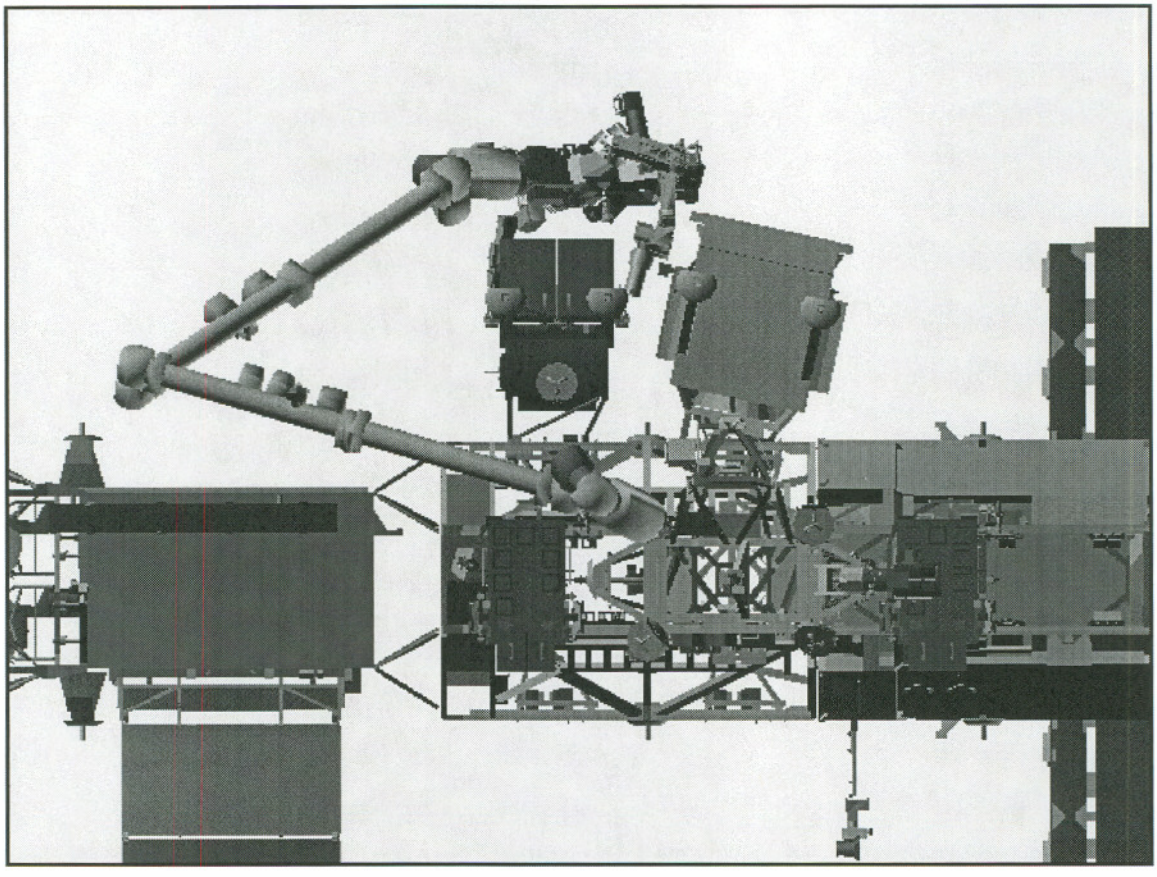

Figure 5: Best Case of SPDM Access to EXP Inboard-Aft Payload
ISS Front View

Affected Area	Gauss Level
SSRMS	1-4
SPDM Body and LEE	6-11
SPDM Rt. Arm (stabilize)	6-16
SPDM Lft. Arm (approach to grapple)	100-240
SPDM Lft. Arm (at grapple)	180-370

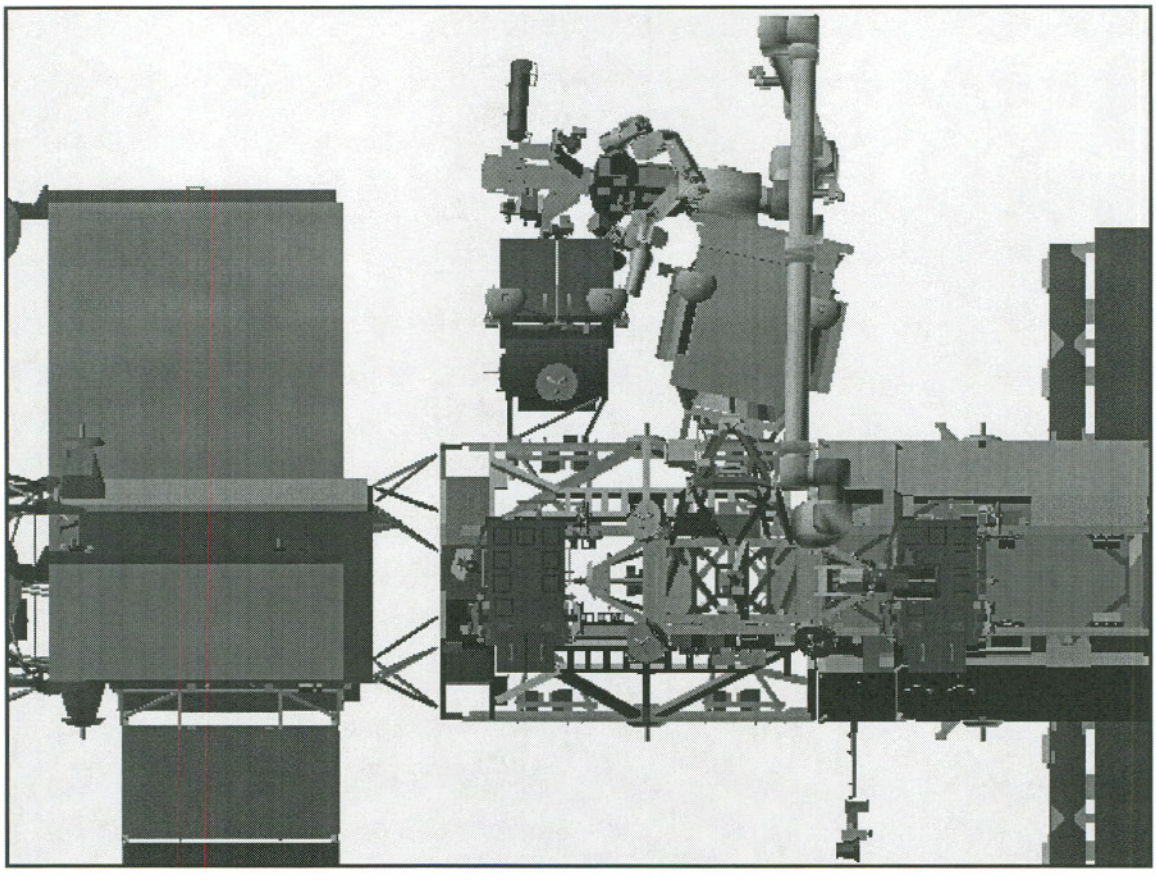

Figure 6: Worst Case of SPDM Access to EXP Inboard-Aft Payload
ISS Front View

Affected Area	Gauss Level
SSRMS	6-27
SPDM Body and LEE	5-23
SPDM Rt. Arm (stabilize)	5-16
SPDM Lft. Arm (approach to grapple)	80-200
SPDM Lft. Arm (at grapple)	100-180

Part 4. – Find the best and worst cases for the SPDM removal of the EXP Inboard-Forward Payload

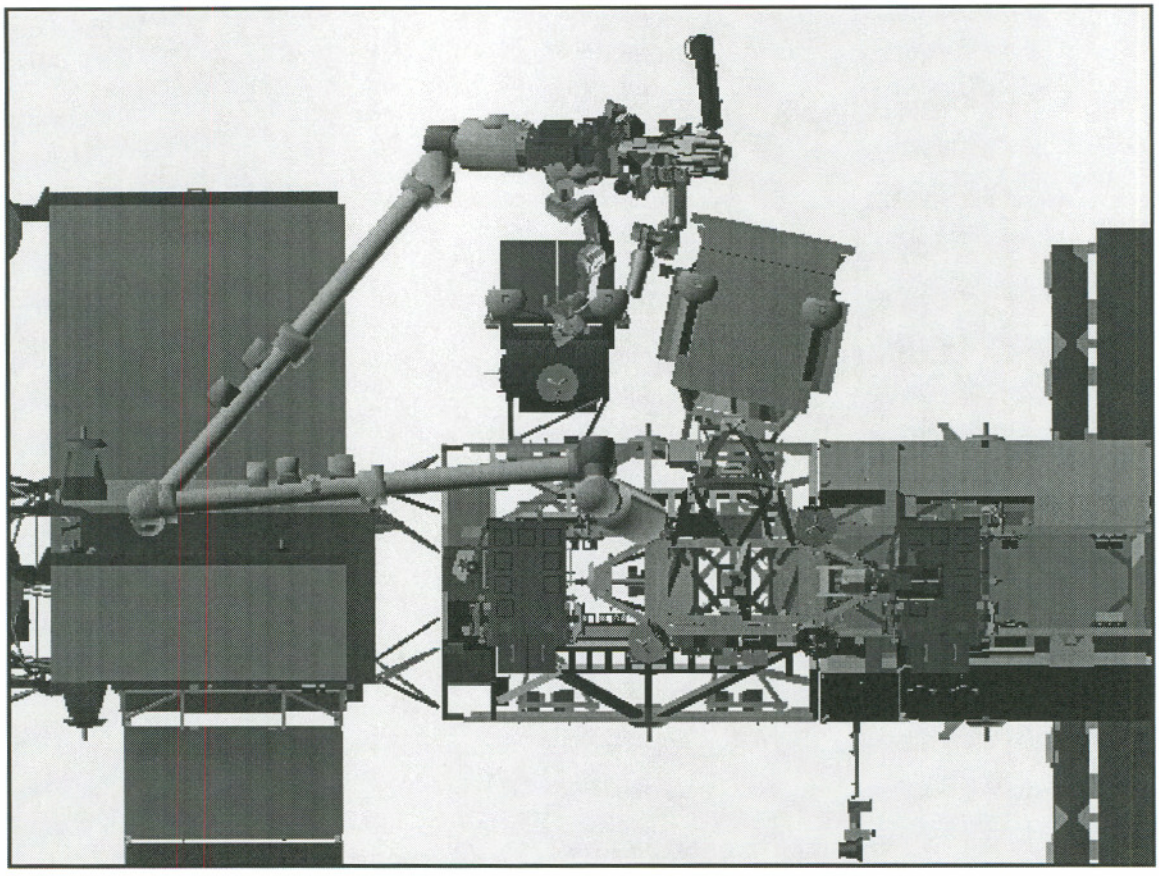

Figure 7: Best Case of SPDM Access to EXP Inboard-Forward Payload
ISS Front View

Affected Area	Gauss Level
SSRMS	1-3
SPDM Body and LEE	4-8
SPDM Rt. Arm (approach to grapple)	100-193
SPDM Rt. Arm (grasping ORU)	150-200
SPDM Lft. Arm (stabilizing)	6-16

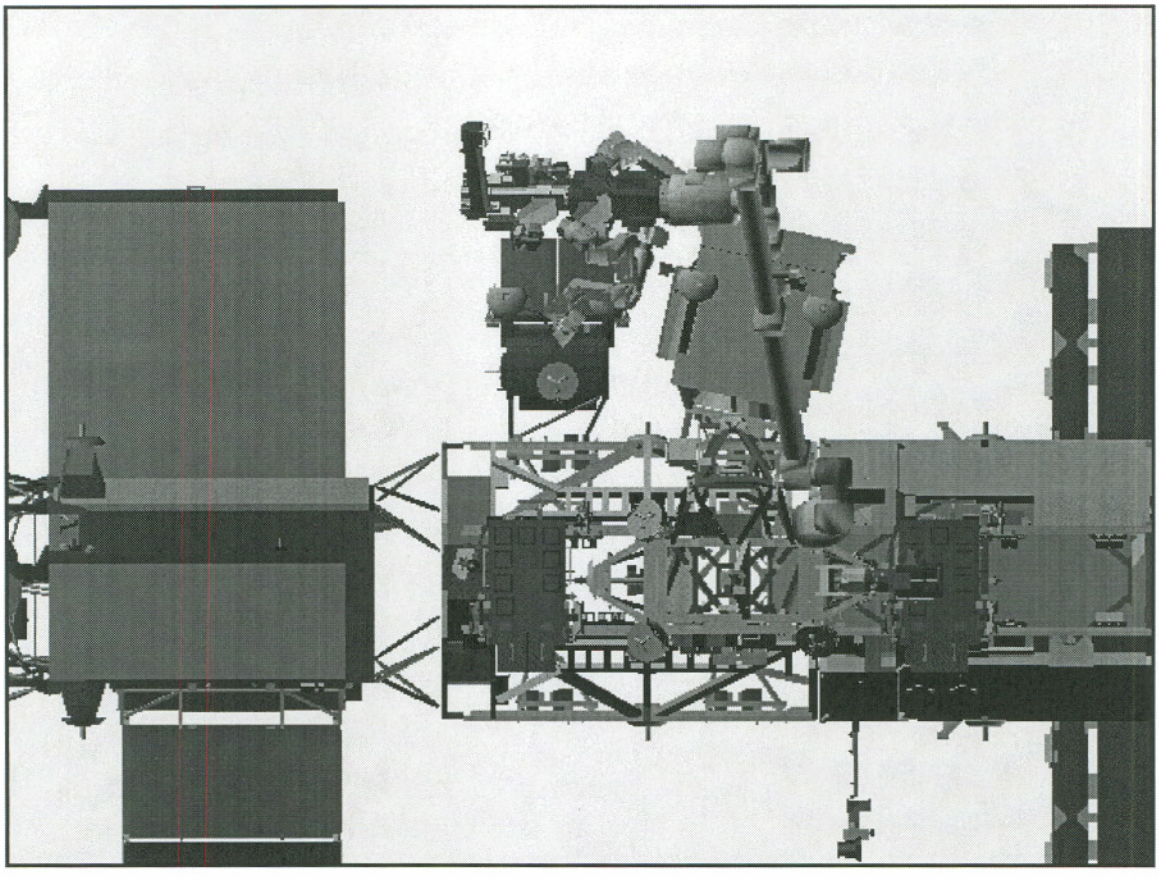

Figure 8: Worst Case of SPDM Access to EXP Inboard-Forward Payload
ISS Front View

Affected Area	Gauss Level
SSRMS	8-14
SPDM Body and LEE	4-15
SPDM Rt. Arm (approach to grapple)	100-200
SPDM Rt. Arm (grasping ORU)	100-370
SPDM Lft. Arm (stabilizing)	6-18

Part 5. – Determine the Magnetic Field Exposure to the Robots During Extraction of the ORUs on S1 and S3.

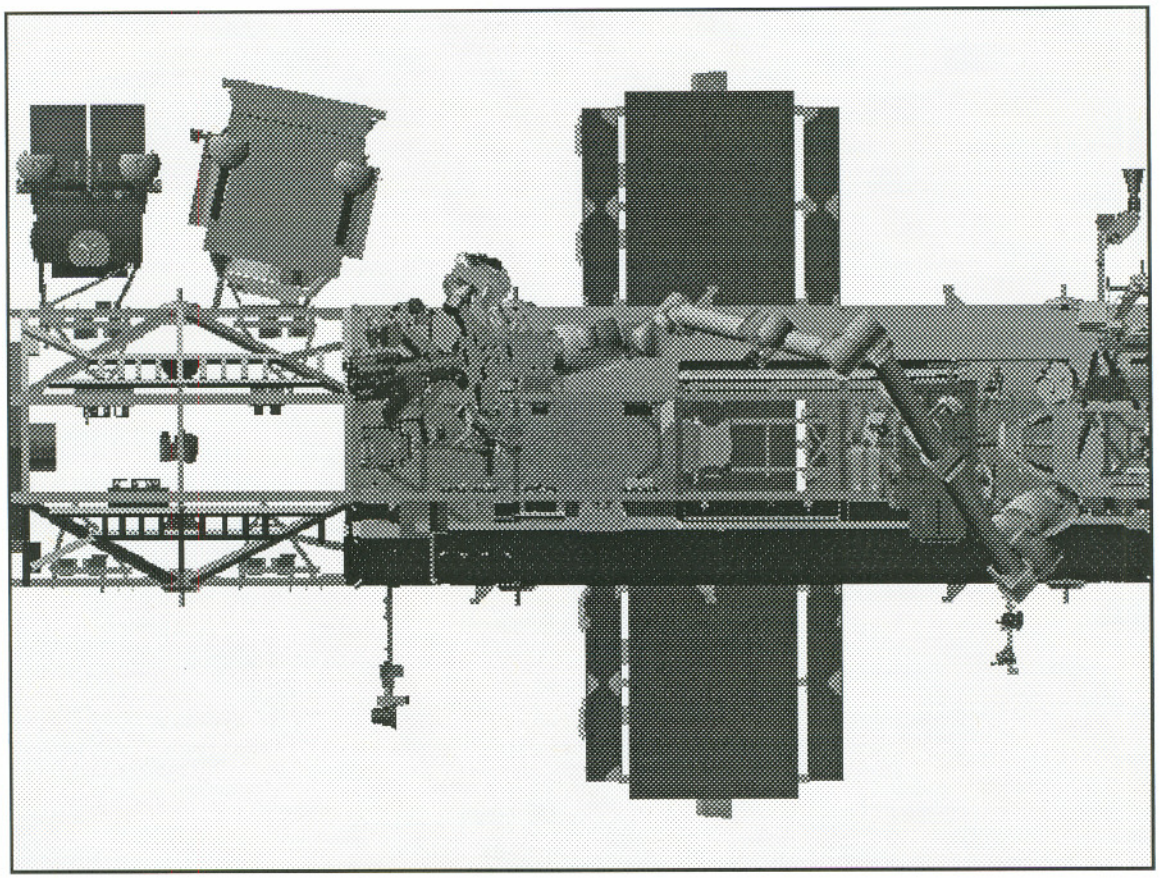

Figure 9: SPDM Access to S1 ORUs
ISS Front View

Affected Area	Gauss Level
SSRMS	0-1
SPDM Body and LEE	1-5
SPDM Right Arm (grasping ORU)	0-2
SPDM Left Arm (stabilizing)	1-4

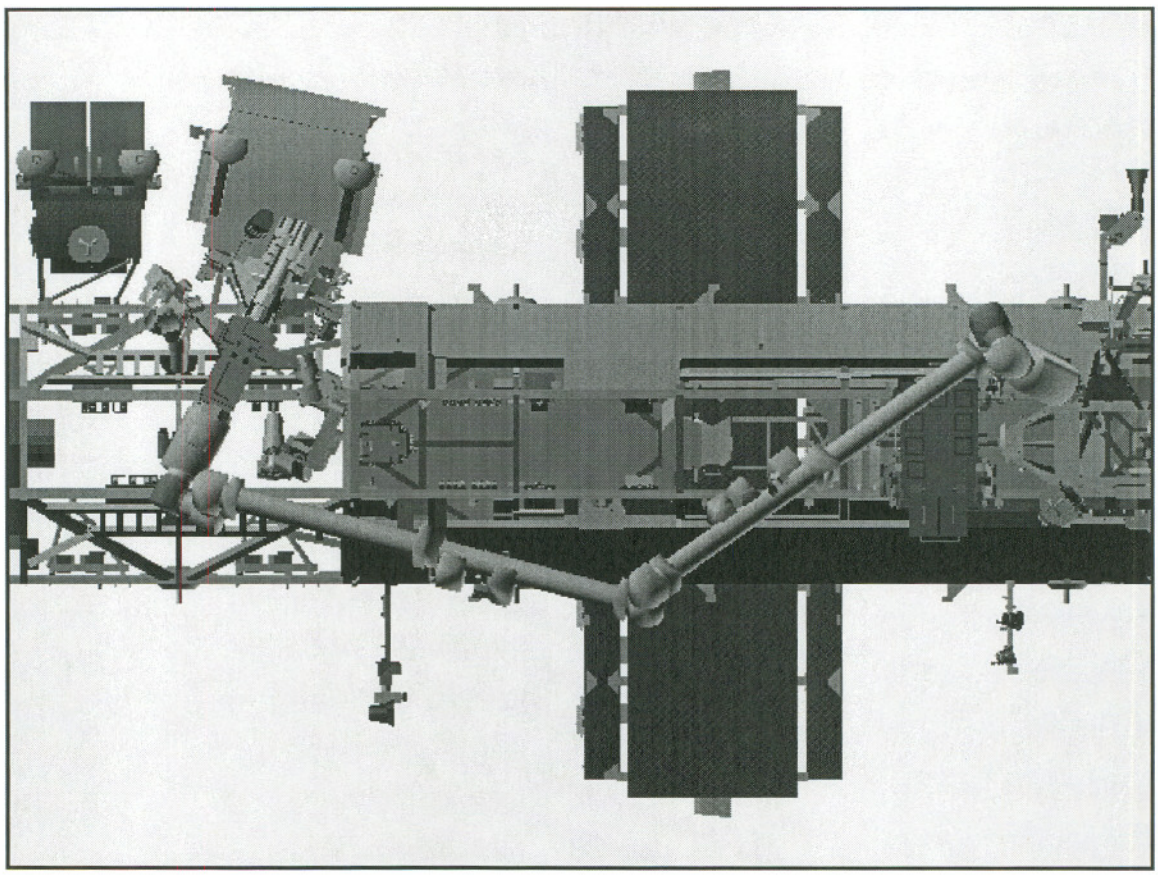

Figure 10: SPDM Access to S3 MDMs
ISS Front View

Affected Area	Gauss Level
SSRMS	0-1
SPDM Body and LEE	2-5
SPDM Rt. Arm (approach to grapple stabilizing fixture)	5-14
SPDM Rt. Arm (stabilizing)	6-11
SPDM Lft. Arm (grasping ORU)	0-3

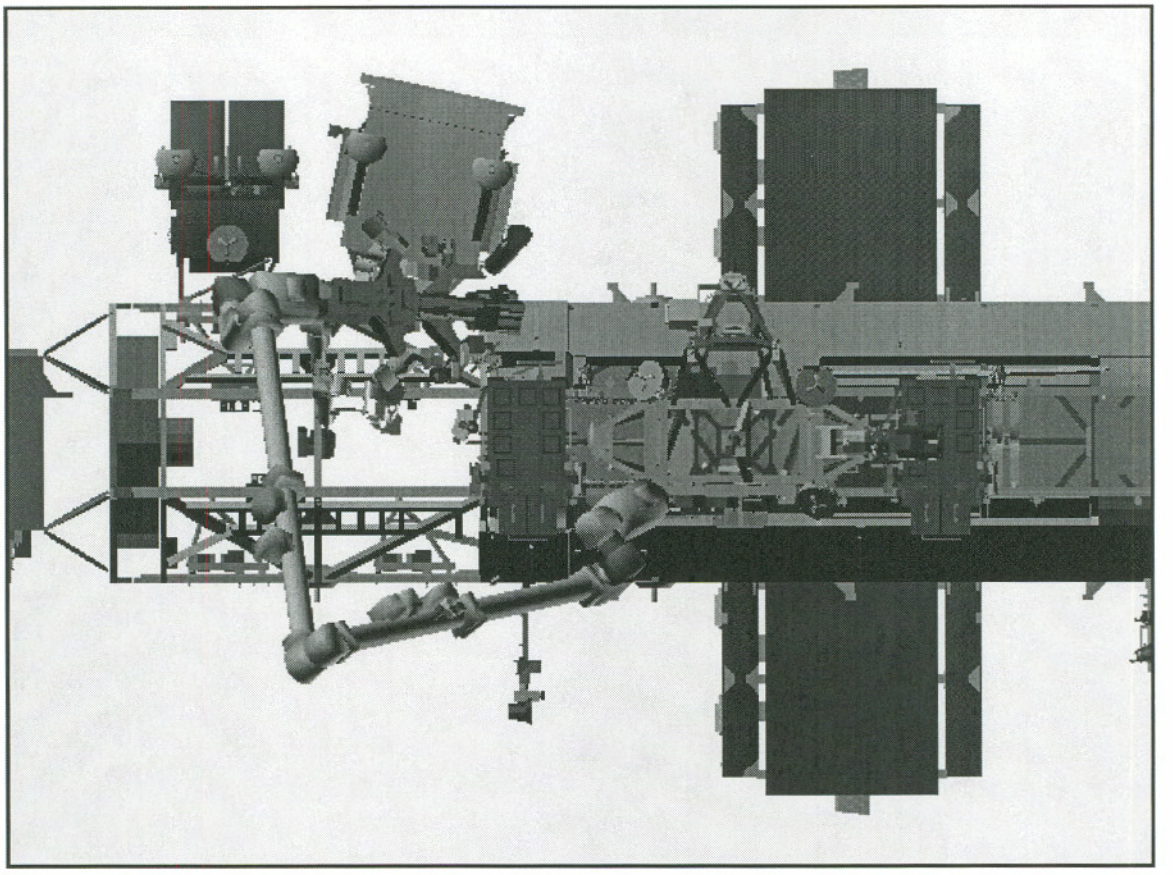

Figure 11: SPDM Access to S3 MT Stop
ISS Front View

Affected Area	Gauss Level
SSRMS	0-2
SPDM Body and LEE	4-9
SPDM Rt. Arm (approach to grapple stabilizing fixture)	4-22
SPDM Rt. Arm (stabilizing)	4-22
SPDM Lft. Arm (grasping ORU)	1-3